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Gait pattern alterations during walking, texting and walking and texting during cognitively distractive task while negotiating common pedestrian obstacles

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Abstract:	Objectives. Mobile phone texting is a common daily occurrence with a paucity of research examining corresponding gait characteristics. To date, most studies have participants walk in a straight line vs. overcoming barriers and obstacles that occur during regular walking. The aim of our study is to examine the effect of mobile phone texting during periods of cognitive distraction while walking and negotiating barriers synonymous with pedestrian traffic. Methods. Thirty participants (18-50y) completed three randomized, counter-balanced walking tasks over a course during: (1) normal walking (control), (2) texting and walking, and (3) texting and walking whilst being cognitively distraction via a standard mathematical test performed while negotiating the obstacle course. We analyzed gait characteristics during course negotiation using a 3-dimensional motion analysis system and a general linear model and Dunnet-Hsu post-hoc procedure the normal walking condition to assess gait characteristic differences. Primary outcomes included the overall time to complete the course time and barrier contact. Secondary outcomes included obstacle clearance height, step frequency, step time, double support phase and lateral deviation. Results. Participants took significantly longer (mean ± SD) to complete the course while texting (24.96±4.20 sec) and during cognitive distraction COG (24.09±3.36 sec) vs. normal walking (19.32±2.28 sec; all, P<0.001). No significant differences were noted for barrier contacts (P = 0.28). Step frequency, step time, double support phase and lateral deviation all increased in duration during the texting and cognitive distraction trial. Texting and being cognitively distracted also increased obstacle clearance versus the walking condition (all, P<0.02). Conclusions. Texting while walking and/or being cognitively distracted significantly affect gait characteristics concordant to mobile phone usage resulting in a more cautious gate pattern. Future research should also examine a similar study in older participants who may be at a greater risk of tripping with such walking deviations.
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If anesthesia, euthanasia or any kind of animal sacrifice is part of the study, please include briefly in your statement which substances and/or methods were applied. Please enter the name of your Institutional Animal Care and Use Committee (IACUC) or other relevant ethics board, and indicate whether they approved this research or granted a formal waiver of ethical approval. Also include an approval number if one was obtained. **Field Permit** Please indicate the name of the institution or the relevant body that granted permission.	
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Please describe where your data may be found, writing in full sentences. **Your answers should be entered into the box below and will be published in the form you provide them, if your manuscript is accepted.** If you are copying our sample text below, please ensure you replace any	Data from "Gait pattern alterations during walking, texting and walking and texting during cognitively distractive task while negotiating common pedestrian obstacles" study whose authors may be contacted at: conrad.earnest@hlkn.tamu.edu

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Additional data availability information:	

Dear Editors

We would be grateful if you would accept an Original Investigation entitlted, "Gait pattern alterations during walking, texting and walking and texting during cognitively distractive task while negotiating common pedestrian obstacles" on our behalf.

The article has not been submitted for or published elsewhere and conforms to the tenets of the Decleration of Helskinki.

The aim of the study is to examine the effects of normal walking versus texting whilst walking and texting, whilst walking and undertaking maths test to impose an additional cognitive distraction. Collectively these factors may lead to inattentional blindness, an elevated risk for tripping/falling and unsafe pedestrians habits. Our study is unique because we designed our obstacle course negotiation to be circuitous as well as negotiating obstacles built and designed to emulate common pedestrian obstacles encountered during outdoor walking.

In our study we examine gait patterns, deviations and barrier contacts, the later serving as a surrogate for potentially tripping. Though we are happy to make our data available to others we do not have a secure repository. However, I can be contacted directly for such data requests.

Sincerely,

Professor Conrad P. Earnest, PhD

Dear Editors

We would be grateful if you would accept our revised paper, “Gait pattern alterations during walking, texting and walking and texting during cognitively distractive task while negotiating common pedestrian obstacles” on our behalf.

In brief, we have extensively re-written the Introduction and Discussion and addressed the reviewers concerns. Though we have made most of the requested suggestions, we do disagree on a few points. In short, these come down to editorial and presentation style, are not issues required of PLoS One and are simply a matter of differing opinion.

Thank you once again for your time in the review of our paper.

Sincerely,

Professor Conrad P. Earnest, PhD

Title. Gait pattern alterations during walking, texting and walking and texting during cognitively distractive task while negotiating common pedestrian obstacles

Running Head. Texting and Cognitive Distraction during Walking

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Key words: Mobile phone, Texting, Gait, Balance

ABSTRACT.

Objectives. Mobile phone texting is a common daily occurrence with a paucity of research examining corresponding gait characteristics. To date, most studies have participants walk in a straight line vs. overcoming barriers and obstacles that occur during regular walking. The aim of our study is to examine the effect of mobile phone texting during periods of cognitive distraction while walking and negotiating barriers synonymous with pedestrian traffic.

Methods. Thirty participants (18-50y) completed three randomized, counter-balanced walking tasks over a course during: (1) normal walking (control), (2) texting and walking, and (3) texting and walking whilst being cognitively distraction via a standard mathematical test performed while negotiating the obstacle course. We analyzed gait characteristics during course negotiation using a 3-dimensional motion analysis system and a general linear model and Dunnet-Hsu post-hoc procedure the normal walking condition to assess gait characteristic differences. Primary outcomes included the overall time to complete the course time and barrier contact. Secondary outcomes included obstacle clearance height, step frequency, step time, double support phase and lateral deviation.

Results. Participants took significantly longer (mean ± SD) to complete the course while texting (24.96±4.20 sec) and during cognitive distraction COG (24.09±3.36 sec) vs. normal walking (19.32±2.28 sec; *all*, $P<0.001$). No significant differences were noted for barrier contacts ($P = 0.28$). Step frequency, step time, double support phase and lateral deviation all increased in duration during the texting and cognitive distraction trial. Texting and being cognitively distracted also increased obstacle clearance versus the walking condition (*all*, $P<0.02$).

Conclusions. Texting while walking and/or being cognitively distracted significantly affect gait characteristics concordant to mobile phone usage resulting in a more cautious gate pattern.

Future research should also examine a similar study in older participants who may be at a greater risk of tripping with such walking deviations.

INTRODUCTION

Mobile phone ownership is increasing internationally. In the United Kingdom, for example, the use of mobile phones has increased from 50% in 2000 to 94% in 2013 [1]. As technology has advanced, so too has the use of "smart phones," which allow users to perform multiple internet-based functions in addition to simply conversing. One of the most often used functions is texting and emailing (herein, text). Current estimates suggest that texting has increased from 20 billion in 2003 to ~39.7 billion text messages sent in 2011 [1]. This rapid growth facilitates communication; yet, carries with it a risk for distraction relative to normal walking behavior such as an increased risk for tripping or secondary injuries to other pedestrians attempting to avoid those who are texting, and deviating from a normal path of ambulation.

While the risk associated with texting is well-recognized during driving, the potential hazards associated with walking are not well established [2-4]. Accordingly, earlier texting and walking research has been observational or conducted in virtual environments, with only three studies using controlled, laboratory conditions [5-15]. Only one of these laboratory studies included obstacle course negotiation [5]. These are important considerations as this line of investigation should ideally be targeted more toward "real life" circumstance. Using driving as an example, a review by Caird et al (2008) found that conversing on a mobile phone while driving significantly reduced reaction time to stimuli [16]. More importantly, Leung et al. (2012) found that texting while walking had a greater detrimental effect on braking reaction time to the extent of having a blood alcohol content of 0.04%, as well as causing more lapses in psychomotor vigilance at blood alcohol levels of 0.04% - 0.10% [17]. Considering a blood alcohol level of 0.08 is illegal in the US and many other countries, the potential risk associated with texting whilst walking is difficult to ignore. Several key points should be noted with regard to current mobile phone use [18].

Overall, texting requires the user to look away from obstacles in their path [19]. Research has also shown that pedestrians are more likely to exhibit riskier road crossing behavior concurrent with mobile phone use and are unable to maintain their non-distracted walking speed or retain spatial information, suggesting that they are not able to effectively divide their attention between the two tasks resulting in inattentional blindness [6,7,9,12,20,21]. Simultaneous texting while walking disrupts gait speed sufficiently to increase road crossing time and this, coupled with riskier road crossing behaviors could increase injury risk [15,22]. Lastly, a natural sequela to such gait alterations is an increased risk for tripping [23,24].

While most studies use fairly simplistic models, we are unaware of any research examining the effects of texting and walking behaviour using a more complicated walking route encompassing common obstacles encountered in daily living. The primary aim of our study is to examine the effect texting on gait characteristics while negotiating common obstacles encountered on a daily basis. To perform our study we will use three treatment conditions: Normal, mobile phone texting and texting during a cognitive challenge. We hypothesize that texting and cognitive challenges will affect normal gait characteristics and increase barrier contacts, a surrogate for tripping, while negotiating steps, ramps and obstacles designed to represent pedestrian traffic.

METHODS

Participants

We recruited thirty participants (18 females; 18-50 years) to take part in our study approved by the University of Bath Department for Health Ethics Advisory Panel. We included only participants who owned their own mobile phone for more than one month and excluded candidates taking medications that may have caused dizziness. All participants signed an informed consent outlining the study aims and procedures. Subsequently, participants then completed questionnaires regarding their current mobile phone use and a physical-activity readiness questionnaire [25]

Experimental Procedures

Before initiating the formal testing procedures all participants completed a familiarization session consisting of completing the obstacle course under each testing condition: walking with no distraction (WLK, control), responding to standardized texting questions on their own phone (TXT) and completing a mental mathematics quiz on a standardized phone (COG). The application used for the mental mathematics quiz during the COG condition (AB Math Lite 5.3) was performed on an iPhone (Apple, California). All participants were instructed not to look at either the messages or the mental mathematics quiz until they began walking. The obstacle course was designed to mimic obstacles one would encounter in everyday life (**Figure 1**) and consisted of seven obstacles: (1) a step over obstacle similar to a curb, (2) a step-on, step-off platform, (3) a set of uneven steps, (4-5) two bollards and (6-7) two dummies, resembling people. We designed all of our obstacles based upon fieldwork measurements taken from the City Centre of Bath (United Kingdom).

We used a 3D optical motion analysis system (Qualisys, Sweden), with 13 Oqus 4 cameras, to collect kinematic data whilst the participants negotiated the obstacle course in each of the conditions. Six reflective markers were attached to each participant using double sided tape: two on each shoe (n=4), one approximately over the 5th metatarsal-phalangeal (MTP) joint and one on the back of the heel, and two on an elasticated band worn around the pelvis. The two pelvis markers were positioned on either side of the spine, approximately over the posterior superior iliac spines. The elasticated band was used to provide a tight fitting surface to which to attach the pelvis markers as the participants undertook the testing in their everyday clothes. We also placed photocell light gates (Powertimer 1.0, Newtest, Finland) at the start and finish of the course to measure time to complete the course. Reflective markers were placed on every obstacle, except the two dummies, on the corners of the front edge of each obstacle. The 3D positions of the markers on the participant and the markers on the obstacles were determined at 100Hz. From these data we calculated the velocity of the participant and various step characteristics as they negotiated the course (**Fig. 1**).

Step Characteristics

To calculate step characteristics we determined the timings of heel strike and toe-off using an algorithm developed by Zeni Jr. et al. (2008). [26] This entailed finding the coordinates of the mid-point of the pelvis markers and subtracting this from the coordinates of heel and 5th MTP markers. Heel strike was defined as the point at which the heel was at a maximum distance in front of the hip and toe-off as the point at which the 5th MTP was at a maximum distance behind the hip. Based upon the timings and positions of heel strike and toe off of each step the following parameters were determined and where appropriate a mean value calculated over the course:

- *Step count*: the number of steps taken for the obstacle course
- *Step time*: the time between the heel strike of one foot and the heel strike of the contralateral foot
- *Step frequency*: the number of steps per second

- *Step length*: the distance between the position of the heel marker at heel strike of one foot and the position of the heel marker at heel strike of the contralateral foot
- *Double support phase*: the time between second foot heel strike and first foot toe off or the time during which both feet were in contact with the ground
- *Barrier clearance*: the difference between the 5th MTP marker vertical coordinate and the barrier vertical coordinate at the time the 5th MTP joint arrived at the obstacle.

We also performed a sub-analysis to examine some of these gait characteristics during the approach and negotiation of the obstacles. *Stair approach* is defined as each respective gait characteristic observed in the 1.5 m immediate prior to negotiating the stairs. *Stair ascent* is defined as each respective gait characteristic observed in the ascending the stairs. *Platform traverse* is each respective gait characteristic observed while traversing the platform.

In addition to the outcome measures defined above, the deviation from a straight path was investigated during the first two sides of the obstacle course. This part of the course was chosen as it involved two clearly defined straight channels with a 90° turn between them (Figure 1). The length of the straight-line path of the first and second sides of the course was determined from the co-ordinates of the centre of the beginning and the end of the path for these two sides (as defined by cones and markers on the ground). The length of the path travelled by the participants was defined as the cumulative displacement of the centre of the pelvis markers along the first and second sides of the course. This was calculated by determining the centre point of the two pelvis markers at each time point, calculating the displacement of this point between each time point and summing these from the beginning of the course until the participant reached the end of the second side. By subtracting the straight path distance from this path travelled distance, the deviation from a straight path was determined.

Statistical Analysis

We examined our data using a general linear model covaried for the control (WLK) condition using SPSS (v21) to examine differences from the WLK condition. Data sphericity was accounted for via a Greenhouse-Geisser correction. Post-hoc analyses were performed using a Dunnett-HSU analysis to compare TXT and COG to the WLK condition. We also performed Pearson correlations between various gait characteristics and barrier contact in an effort to associate potential gait characteristics and tripping risk. All data is presented as mean ± standard deviation (SD) or 95% confidence intervals were appropriate. Statistical significance was established at $P \leq 0.05$. The effect size is presented as the partial eta squared for each analysis.

RESULTS.

Course Performance Characteristics.

We have presented the overall findings for negotiating the complete course in **Table 1**. Overall, we found that it took significantly longer to complete the course due to slower walking speeds under the TXT and COG conditions vs. WLK (*all*, P<0.001, **Fig. 2A**). Supporting these observations are observations for significantly shorter step lengths (**Fig. 2B**), lower step frequencies, longer double support phases (**Fig. 2C**), and greater obstacle clearance heights while TXT and COG vs. WLK (all, P<0.001, **Fig. 2D**). While the COG condition was significantly different to TXT for walking speed (P<0.02) and step frequency (P<0.04), no other significant differences were noted between the TXT and COG conditions. Despite these alterations in gait characteristics we did not observe any changes in barrier contacts during any treatment condition (P = 0.10).

Performance Characteristics for Individual Obstacles.

We have presented the findings for negotiating each individual obstacle in **Table 2**.

Step Approach. When negotiating the 1.5 m approach to the steps, we did not observe a significant difference to the step count or step frequency on the approach. However, we did observe a significantly greater length of time to the approach for the COG condition and a strong trend for significance during the TXT condition (P=0.07) due to a significant reduction in step length and double support phase for the TXT (P=0.011) and COG conditions (P=0.004). While we also observed a greater step clearance height for the TXT condition (P<0.001), we did no observe a significant for the COG condition.

Platform Traverse. Overall, it took longer to negotiate the platform during the TXT and COG conditions (all, P<0.001) vs WLK with no distraction. This was due, in part, to a greater step count for the TXT condition (P=0.004) and strong trend for the COG condition (P=0.06). Other contributing factors for this observation included a shorter step frequency for the COG condition (P<0.001) and shorter step lengths for the TXT and COG condition (*both*, P<0.001). No significant differences were noted for the double support phase or clearance height.

Stairs Ascent. Negotiating the stairs took significantly longer during the TXT (P<0.001) and COG conditions P=0.008). Contributing factors for this observation included a greater step count during the TXT and COG conditions (P<0.001), a greater step frequency during the TXT (P=0.005) and COG conditions (P=0.014), and greater clearance heights whilst negotiating the stairs for the TXT (P=0.003) and COG conditions (P<0.001). No significant differences were noted for step length or the double support phase of stair ascent.

DISCUSSION

The primary aim of our study was to examine the effect of a TXT and COG challenge on gait characteristics during concomitant walking and mobile phone use. Our primary findings show that TXT and COG significantly shorten step length, reduce step frequency, lengthen double phase support and increase obstacle clearance height. Thus, we accept our first research hypothesis that TXT and COG will significantly alter gait characteristics during walking. The findings from our secondary outcome analysis also show similar patterns for each respective obstacle encountered over the course. Specifically, participants altered their approach to stairs, subsequent stair ascent obstacle step clearance height and the negotiation of platforms under the TXT and COG conditions. A natural sequelae to our findings would be to proffer that such gait alterations might lead to an increased risk or tripping. However, we examined this potential via the surrogate measure of barrier contacts and despite the alterations we observed during our study, we did not observe any significant alterations in barrier contact during course negotiation under any treatment condition suggesting that participants adopted a protective gait pattern to avoid such a consequence. Therefore, we reject our hypothesis that TXT and COG would increase the occurrence barrier contact and that the connection of gait alterations and deviations from walking a straight path become tenuous.

As it pertains to clearance height our findings are consistent to others with a few exceptions that may be related to age. McFadyn and Prince have shown that aging may influence step clearance height as older participants in their study decreased their clearance height over obstacles, suggesting that they are more likely to make obstacle contact and, hence, would be more likely to trip over obstacles [27]. In contrast, however, Lu et al. (2006) showed that older participants tended to increase clearance height in proportion to the height of the obstacle, a finding also found by others [28-30]. Our findings support these latter observations as we observed an increase in obstacle clearance heights within our study. While our study used a fairly broad age demographic we were unable to show any difference between age and obstacle clearance heights between young (i.e., university age) and participants who would be characterized as middle-age. It should be noted, however, that much like alterations in surrogate gait characteristics associated with tripping, such as deviation from an intended course and barrier clearance heights, a more salient measure short of actual tripping is actual barrier contact.

In our study we observed no significant differences in barrier contacts regardless of the age of the participant. Our findings are generally consistent with those of others, as previous research has shown that unless time constraints are imposed on participants there are no differences between younger and older adults [27,31,32]. It appears, therefore, that the participants in our study demonstrated a "protective" alteration in gait patterning in order to minimize tripping risk. This is likely due to the adoption of a more conservative locomotion strategy, which involves decreased walking velocity and foot placement adjustment before encountering an obstacle [29,30,33]. Whether this change in gait pattern is conscious or sub-conscious is indeterminable from our study design. Though this can be attributed to differences in study methods, our findings support the observation that a young to middle age population adopts a more conservative locomotion strategy, which ultimately acts as a "safety mechanism" to avoid obstacles and decrease momentum should obstacle contact occur. This decrease in walking velocity in the face of a TXT and COG challenge is supported by previous literature, as well as our current study findings showing a reduction in total course completion time, walking velocity and obstacle negotiation [10,22,34]. While the effect of TXT and/or COG may not affect tripping, per se, there are other areas of walking behaviours that warrant further attention.

Overall, texting whilst walking increases ones time spent looking away from obstacles by as much as 400% [19]. Theoretically, such inattentiveness could increase the likelihood for accidents during road crossings. In a more humorous example, Hyman et al. (2010) showed that people using their mobile phones were less likely to notice a unicycling clown performing along their walking route [8] Of more serious consequence is the observation that pedestrians using mobile phones are unable to retain spatial information as they divide their time between the two tasks resulting in what is known as “inattentional blindness” [9,20,21]. A potential consequence of inattentional blindness may an attenuation of safe pedestrianism as previous research has shown that walking and simultaneous mobile phone use leads to a fourfold increase in riskier road crossing behaviors [6,7,12,19]. Curiously, riskier crossing behaviors tend to be more prevalent in females [12]. Several studies have also found that texting while walking disrupts gait more than conversing on a phone causing pedestrians to take ~18% longer to cross the road and four times more likely to exhibit at least one unsafe crossing behavior, such as taking longer to cross the street, missing safer crossing opportunities, taking longer to initiate crossing when a safe gap is available, looking left and right less often, spending more time looking away from the road, being more likely to initiate crossing before traffic stops and being more likely to be hit or almost hit by an oncoming vehicle [12,15,22] Thus, slower gait speeds coupled to inattentional blindness due to TXT and/or COG distraction and riskier crossing behaviors may culminate in more frequent auto-pedestrian accidents [10,35].

Ultimately, the act of multi tasking leads to one of the tasks having to be prioritized.[36,37] Some theories suggest that the posture and gait function are prioritized over cognitive demands, as posture and gait operate at a more subconscious level [38]. This has been challenged in recent work suggesting that there are several factors that dictate task prioritization, and posture and gait patterns can be subsequently affected by the introduction of a secondary task [10,39]. In many cases the cognitive aspects of dual tasking are frequently prioritized over postural and gait elements, which subsequently can account for decreased walking performance during texting. Ebersbach and colleagues show support for these finding by demonstrating gait alterations whilst being placed within a dual tasking condition [40]. The results from the present study support this mechanism given that participants displayed adaptive changes in gait patterns during the TXT and COG conditions. However, it is difficult to say from the present findings whether the induced changes to walking performance resulted from dual tasking or via the visual impairment introduced by the requirement to focus on a mobile phone.

Our study presents for the first time gait characteristics associated with TXT and COG challenges while negotiating a serpentine course designed to emulate common outdoor walking tasks. Though we attempted to examine potential gender and aging affects by recruiting a more mature population, we feel that the age gap was insufficient to distinguish more robust obstacle course differences and we are therefore unable to generalize our findings beyond the age limits associated within our study cohort. We also cannot generalize to the potential effects of TXT and COG distractions associated with mobile phone use beyond our laboratory conditions. Our study is strengthened by our use of a crossover design whereby participants participated in all treatment conditions as well as our incorporation of an unfamiliar phone to decrease any bias due to familiarity. In retrospect, our study would be enhanced by the use of eye-tracking technology, which would allow for more conclusions to be drawn regarding the attention prioritization encountered during course negotiation.

The present study supports the suggestion that gait is not a completely automated function and is altered by the addition of TXT and COG tasks. The minimal differences between the TXT and COG conditions in the present study potentially show that even though the conditions could require different cognitive responses, people are used to interacting with mobile technology whilst walking and can even be given a novel task on a foreign phone and still display similar gait characteristics to that of performing an everyday task on their personal phone. Based on our findings, participants display a more conservative and hesitant gait in response to the dual-tasking situation of COG and TXT. The present study has, however, progressed the relevant field of research via the use of a more sophisticated methodology, which has in turn provided novel insight into the relationship between mobile phone usage gait alterations. Our findings are additionally important from a population perspective as an increasing body of research advocates smartphone technology as a means of increase physical activity levels for prevention, primary care and rehabilitation [41,42].

Acknowledgements. None.

Figures.

Figure 1. Schematic and dimensional representation of the obstacle course where, (**A**) Step over; length = 0.105 m; width = 0.720 m; height 0.105 m, (**B**) Platform; length = 2.030 m; width = 0.750 m; height = 0.092 m, (**C**) Stair 1; length = 0.400 m; width = 0.400 m; height = 0.205 m, (**D**) Stair 2; length = 0.500 m; width = 0.500 m; height = 0.300 m, (**E**) Stair 3; length = 0.585 m; width = 0.910 m; height = 0.110 m, (**F**) Model people; length = 0.420 m; width = 0.530 m; height = 1.880 m

Figure 2. Data represent mean and 95% confidence interval information for Course Time (panel A), Step Length (panel B), Double Support phase of walking (panel C) and Obstacle Clearance Height for course barriers (panel D). Statistical notations are: * 0.001 and ¶ 0.02.

Table 1: Course performance characteristics of participants negotiating obstacle course

	Distraction Challenge	Mean	SD	Significance vs. WLK	Partial Eta Squared
Course Time (sec)	Walk	19.32	2.3		
	Text	24.96	4.2	< 0.001	
	Cognitive	24.09	3.4	< 0.001	0.79
Walk Speed (m/sec)	Walk	0.78	0.1		
	Text	0.61	0.1	< 0.001	
	Cognitive [a]	0.63	0.1	< 0.001	0.88
Lateral Deviation from Straight Path	Walk	2.71	0.3		
	Text	2.76	0.3	NS	
	Cognitive	2.77	0.6	NS	0.04
Barrier Contact (n)	Walk	0.13	0.4		
	Text	0.23	0.4	NS	
	Cognitive	0.10	0.3	NS	0.10
Step Length (cm)	Walk	42.00	30.0		
	Text	36.00	20.0	< 0.001	
	Cognitive	37.00	20.0	< 0.001	0.87
Step Frequency (steps/sec)	Walk	1.84	0.2		
	Text	1.67	0.2	< 0.001	
	Cognitive [b]	1.71	0.2	< 0.001	0.62
Double Support Phase (sec)	Walk	170.00	30.0		
	Text	200.00	30.0	< 0.001	
	Cognitive	200.00	40.0	< 0.001	0.26
Obstacle Clearance Height (mm)	Walk	94.00	13.0		
	Text	111.00	19.0	< 0.001	
	Cognitive	110.00	23.0	<0.02	0.40

a = Significant vs. Text = 0.015
b = Significant vs. Text = 0.035

Table 2: Performance characteristics for individual obstacles

			Mean	SD	Significance vs. WLK	Partial Eta Squared
Time (ms)	Stair	Walk	550.00	60.0		
	Approach	Text	580.00	90.0	0.074	
		Cognitive	590.00	70.0	0.004	0.267
	Platform	Walk	630.00	60.0		
	Traverse	Text	710.00	110.0	< 0.001	
		Cognitive	710.00	100.0	< 0.001	0.453
	Stair	Walk	480.00	130.0		
	Ascent	Text	570.00	90.0	0.000	
		Cognitive	550.00	70.0	0.008	0.414
Step count (n)	Stair	Walk	1.24	0.4		
	Approach	Text	1.43	0.5		
		Cognitive	1.38	0.5		0.140
	Platform	Walk	1.07	0.3		
	Traverse	Text	1.40	0.5	0.004	
		Cognitive	1.24	0.4	0.060	0.270
	Stair	Walk	1.10	0.3		
	Ascent	Text	1.53	0.5	< 0.001	
		Cognitive	1.34	0.5	< 0.001	0.400
Step Frequency (steps/sec)	Stair	Walk	1.83	0.2		
	Approach	Text	1.89	0.5	NS	
		Cognitive	1.83	0.5	NS	0.001
	Platform	Walk	1.61	0.2		
	Traverse	Text	1.55	0.5	NS	
		Cognitive	1.44	0.2	< 0.001	0.556
	Stair	Walk	2.17	0.6		
	Ascent	Text	1.80	0.4	0.005	
		Cognitive	1.87	0.3	0.014	0.266
Step Length (cm)	Stair	Walk	69.70	17.1		
	Approach	Text	61.20	7.7	0.011	
		Cognitive	59.90	10.7	0.004	0.268
	Platform	Walk	72.40	7.0		
	Traverse	Text	58.40	15.7	0.001	
		Cognitive	64.60	9.4	0.001	0.486
	Stair	Walk	54.40	23.8		
	Ascent	Text	48.70	18.2	NS	
		Cognitive	50.80	14.6	NS	0.087
Double Support Phase (ms)	Stair	Walk	150.00	30.0		
	Approach	Text	170.00	40.0	0.004	
		Cognitive	170.00	20.0	< 0.001	0.483

	Platform	Walk	170.00	70.0		
	Traverse	Text	190.00	40.0	NS	
		Cognitive	200.00	80.0	NS	0.097
	Stair	Walk	220.00	120.0		
	Ascent	Text	290.00	150.0	NS	
		Cognitive	280.00	160.0	<0.001	0.440
Clearance Height (mm)	Stair	Walk	135.00	26.0		
	Approach	Text	159.00	41.0	<0.001	
		Cognitive	148.00	51.0	NS	0.365
	Platform	Walk	65.00	26.0		
	Traverse	Text	65.00	22.0	NS	
		Cognitive	65.00	32.0	NS	0.000
	Stair	Walk	73.00	14.0		
	Ascent	Text	97.00	37.0	0.003	
		Cognitive	99.00	22.0	<0.001	0.615

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Title. Gait pattern alterations during walking, texting and walking and texting during cognitively distractive task while negotiating common pedestrian obstacles

Running Head. Texting and Cognitive Distraction during Walking

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ABSTRACT.

Objectives. Mobile phone texting is a common daily occurrence with a paucity of research examining corresponding gait characteristics. To date, most studies have participants walk in a straight line vs. overcoming barriers and obstacles that occur during regular walking. The aim of our study is to examine the effect of mobile phone texting during periods of cognitive distraction while walking and negotiating barriers synonymous with pedestrian traffic.

Methods. Thirty participants (18-50y) completed three randomized, counter-balanced walking tasks over a course during: (1) normal walking (control), (2) texting and walking, and (3) texting and walking whilst being cognitively distraction via a standard mathematical test performed while negotiating the obstacle course. We analyzed gait characteristics during course negotiation using a 3-dimensional motion analysis system and a general linear model and Dunnet-Hsu post-hoc procedure the normal walking condition to assess gait characteristic differences. Primary outcomes included the overall time to complete the course time and barrier contact. Secondary outcomes included obstacle clearance height, step frequency, step time, double support phase and lateral deviation.

Results. Participants took significantly longer (mean ± SD) to complete the course while texting (24.96±4.20 sec) and during cognitive distraction COG (24.09±3.36 sec) vs. normal walking (19.32±2.28 sec; *all*, $P<0.001$). No significant differences were noted for barrier contacts ($P = 0.28$). Step frequency, step time, double support phase and lateral deviation all increased in duration during the texting and cognitive distraction trial. Texting and being cognitively distracted also increased obstacle clearance versus the walking condition (*all*, $P<0.02$).

Conclusions. Texting while walking and/or being cognitively distracted significantly affect gait characteristics concordant to mobile phone usage resulting in a more cautious gate pattern.

Future research should also examine a similar study in older participants who may be at a greater risk of tripping with such walking deviations.

INTRODUCTION

Mobile and Smartphone has increased internationally and it is now estimated that Smartphone ownership will increase from an estimated 34.3% in 2011 to a projected 58.2% in 2015 in the United Kingdom [1,2]. Coupled to Smartphone ownership is an increase in mobile messaging inclusive of texting, SMS, Internet, social media access and emailing. For simplicity we will use “text” to denote various Internet communication functions. To this end, texting has increased in the United Kingdom from 27 billion in 2004 to 129 billion in 2012 [3]. While text growth facilitates communication it also increases the risk of distraction during walking, which may in turn carry with it an increased risk for tripping, collision or secondary injuries to other pedestrians attempting to avoid those who are texting and deviating from a normal path of ambulation. While the risk associated with texting is well-recognized during driving, the potential hazards associated with walking are not as well established [4-6].

Few studies have investigated walking and texting and fewer yet the simultaneous negotiation of an obstacle course [7]. This is an important consideration as “real life” requires the user to look away from pathway obstacles in order to text [8]. As such, texting while walking disrupts gait speed, potentially increasing road crossing time and riskier road crossing behaviors, possibly increasing tripping and accident risk [9-12]. While most studies use fairly simplistic models, we are unaware of research using more circuitous obstacle courses designed and built to represent common pedestrian obstacles such as curbs, people, steps, etc. The primary aim of our study is to examine the effect texting on gait characteristics while negotiating common pedestrian obstacles. We hypothesize that texting will affect normal gait characteristics and increase barrier contacts, a surrogate for tripping, while negotiating steps, ramps and obstacles representing pedestrian traffic.

METHODS

Participants

We recruited thirty participants (18 females; 18-50 years) to take part in our study approved by the University of Bath Department for Health Ethics Advisory Panel. We included only participants who owned their own mobile phone for more than one month and excluded candidates taking medications that may cause dizziness. All participants signed an informed consent outlining the study aims and procedures. Subsequently, participants completed questionnaires regarding their current mobile phone use and a physical-activity readiness questionnaire [13].

Experimental Procedures

Before initiating formal testing procedures, participants completed a familiarization session of the obstacle course under each testing condition: (1) walking with no distraction (WLK, control), (2) responding to standardized texting questions on their own phone (TXT) and (3) completing a mental mathematics quiz (AB Math Lite 5.3) on an iPhone™ (Apple, Cupertino, CA US phone (COG). All participants were instructed not to look at either the messages or the mental mathematics quiz until they began walking. All walking conditions were administered in a randomized, counter-balanced manner.

The obstacle course was designed to mimic obstacles one would encounter in everyday life (**Figure 1**) and consisted of seven obstacles designed and based on fieldwork within the City Centre of Bath, UK:

(1) An obstacle resembling a curb to step over,

(2) A platform to step-on, step-off platform,

(3) A set of uneven steps,

(4-5) Two traffic bollards to step around and,

(6-7) Two dummies of sufficient height representing model people for participants to step around

We used a 3D optical motion analysis system (Qualisys, Sweden), with 13 Oqus 4 cameras set-up to collect kinematic data whilst the participants negotiated the obstacle course in each of the conditions. Six reflective markers were attached to each participant using double sided tape: two on each shoe (n=4), one approximately over the 5th metatarsal-phalangeal (MTP) joint and one on the back of the heel, and two on an elasticated band worn around the pelvis. The two pelvis markers were positioned on either side of the spine, approximately over the posterior superior iliac spines. The elasticated band was used to provide a tight fitting surface to which to attach the pelvis markers as the participants undertook the testing in their everyday clothes. We also placed photocell light gates (Powertimer 1.0, Newtest, Finland) at the start and finish of the course to measure time to complete the course. Reflective markers were placed on every obstacle on the corners of the front edge of each obstacle except for the two model people. The 3D positions of the markers on the participant and the markers on the obstacles were determined at 100Hz. From these data we calculated the velocity of the participant and various step characteristics as they negotiated the course (**Fig. 1**). Data from Qualisys was imported into an Excel spreadsheet in order to perform requisite calculations. No filtering was applied or data adjusted we only looked at marker displacement of the markers and did not investigate velocity or acceleration.

Step Characteristics

To calculate step characteristics we determined the timings of heel strike and toe-off using an algorithm developed by Zeni Jr. et al. (2008). [14] This entailed finding the coordinates of the mid-point of the pelvis markers and subtracting this from the coordinates of heel and 5th MTP markers. Heel strike was defined as the point at which the heel was at a maximum distance in front of the hip and toe-off as the point at which the 5th MTP was at a maximum distance behind the hip. Based upon the timings and positions of heel strike and toe off of each step the following parameters were determined and where appropriate a mean value calculated over the course:

- *Step count*: the number of steps taken for the obstacle course
- *Step time*: the time between the heel strike of one foot and the heel strike of the contralateral foot
- *Step frequency*: the number of steps per second
- *Step length*: the distance between the position of the heel marker at heel strike of one foot and the position of the heel marker at heel strike of the contralateral foot
- *Double support phase*: the time between second foot heel strike and first foot toe off or the time during which both feet were in contact with the ground
- *Barrier clearance*: the difference between the 5^{th} MTP marker vertical coordinate and the barrier vertical coordinate at the time the 5th MTP joint arrived at the obstacle.

We also performed a sub-analysis to examine some of these gait characteristics during the approach and negotiation of the obstacles. *Stair approach* is defined as each respective gait characteristic observed in the 1.5 m immediate prior to negotiating the stairs. *Stair ascent* is defined as each respective gait characteristic observed in the ascending the stairs. *Platform traverse* is each respective gait characteristic observed while traversing the platform.

In addition to the outcome measures defined above, the deviation from a straight path was investigated during the first two sides of the obstacle course. This part of the course was chosen as it involved two clearly defined straight channels with a 90° turn between them (Figure 1). The length of the straight-line path of the first and second sides of the course was determined from the co-ordinates of the centre of the beginning and the end of the path for these two sides (as defined by cones and markers on the ground). The length of the path travelled by the participants was defined as the cumulative displacement of the centre of the pelvis markers along the first and second sides of the course. This was calculated by determining the centre point of the two pelvis markers at each time point, calculating the displacement of this point between each time point and summing these from the beginning of the course until the participant reached the end of the second side. The deviation from walking a straight path was determined by subtracting the straight path distance from the actual path travelled.

Statistical Analysis

We examined our data using a general linear model covaried for the control/WLK condition using SPSS (v21). Data sphericity was accounted for via a Greenhouse-Geisser correction. Post-hoc analyses were performed using a Dunnett-HSU analysis to compare TXT and COG to the WLK condition. We also performed Pearson correlations between various gait characteristics and barrier contact in an effort to associate potential gait characteristics and tripping risk. All data is presented as mean ± standard deviation (SD) or 95% confidence intervals where appropriate. Statistical significance was established at $P \leq 0.05$. The effect size is presented as the partial eta squared for each analysis.

RESULTS.

Course Performance Characteristics

We have presented the overall findings for negotiating the complete course in **Table 1**. Overall, we found that it took significantly longer to complete the course due to slower walking speeds under the TXT and COG conditions vs. WLK (*all*, P<0.001, **Fig. 2A**). In support of these observations, participants exhibited significantly shorter step lengths (**Fig. 2B**), lower step frequencies, longer double support phases (**Fig. 2C**), and greater obstacle clearance heights while TXT and COG vs. WLK (all, P<0.001, **Fig. 2D**). While the COG condition was significantly different to TXT for walking speed (P<0.02) and step frequency (P<0.04), no other significant differences were noted between the TXT and COG conditions. Despite these alterations in gait characteristics we did not observe any changes in barrier contacts during any treatment condition (P = 0.10).

Performance Characteristics for Individual Obstacles

We have presented the findings for negotiating each individual obstacle in **Table 2**.

Step Approach. When negotiating the 1.5 m approach to the steps, we did not observe a significant difference to the step count or step frequency on the approach. However, we did observe a significantly greater length of time to the approach for the COG condition and a strong trend for significance during the TXT condition (P=0.07) due to a significant reduction in step length and double support phase for the TXT (P=0.011) and COG conditions (P=0.004). While we also observed a greater step clearance height for the TXT condition (P<0.001), we did no observe a significant for the COG condition.

Platform Traverse. Overall, it took longer to negotiate the platform during the TXT and COG conditions (all, P<0.001) vs. WLK with no distraction. This was due, in part, to a greater step count for the TXT condition (P=0.004) and strong trend for the COG condition (P=0.06). Other contributing factors for this observation included a shorter step frequency for the COG condition (P<0.001) and shorter step lengths for the TXT and COG condition (*both*, P<0.001). No significant differences were noted for the double support phase or clearance height.

Stairs Ascent. Negotiating the stairs took significantly longer during the TXT ($P<0.001$) and COG conditions $P=0.008$). Contributing factors for this observation included a greater step count during the TXT and COG conditions ($P<0.001$), a greater step frequency during the TXT ($P=0.005$) and COG conditions ($P=0.014$), and greater clearance heights whilst negotiating the stairs for the TXT ($P=0.003$) and COG conditions ($P<0.001$). No significant differences were noted for step length or the double support phase of stair ascent.

DISCUSSION

The primary aim of our study was to examine the effect of a TXT and COG challenge on gait characteristics during concomitant walking and mobile phone use. Our primary findings show that TXT and COG significantly shorten step length, reduce step frequency, lengthen double phase support and increase obstacle clearance height. Our secondary outcome analysis also shows a similar pattern alterations relative to each respective obstacle encountered over the course. Specifically, participants altered their approach to stairs, subsequent stair ascent obstacle step clearance height and the negotiation of platforms under the TXT and COG conditions. Thus, we accept our first research hypothesis that TXT and COG significantly alters gait characteristics during walking. While one might infer that these alterations in gait might increase the risk for tripping, our surrogate analysis (i.e., barrier contacts) showed no significant differences between any treatment conditions. Therefore, we reject our hypothesis that TXT and COG would increase the occurrence barrier contact and that the connection between gait alterations, deviations from walking a straight path and tripping becomes tenuous. Our results, in conjunction with others [15-17], suggest that those who walk and text adopt a "protective" gait pattern alteration in order to minimize the risk of potential accidents.

Overall, the adoption of a more conservative locomotion strategy involves a decreased walking velocity and foot placement adjustment before encountering an obstacle [15-17]. Some hypothesize that when faced with a cognitive challenge, posture and gait function are prioritized over cognitive demands, as posture and gait operate at a more subconscious level [18,19]. Whether the change in gait pattern in our study is conscious or sub-conscious is currently indeterminable; however, the decrease in walking velocity associated with a TXT and COG challenge in our study coupled with previous literature examining other populations examining walking support this hypothesis [10,15-17,20,21]. In essence, when faced with the dual task challenge of walking and texting while undergoing a cognitive challenge, participants decrease their walking speed to avoid accidents [22]. The results from the present study support this mechanism given that participants displayed adaptive changes in gait patterns during the TXT and COG conditions. As it pertains to texting our findings differ to those recently published by Plummer et al (2015) who demonstrated no significant gait alterations using a single and dual task assessment of walking and texting in 32 young adults (18 - 30 y) [19]. We propose several reasons for these differences.

First, Plummer et al (2015) used a straight course pathway free of obstacles, while our course was circuitous and incorporated common pedestrian obstacles. Second, we used a broader age range (18–50 y), which may have introduced a "familiarity" component as younger individuals are more likely to be familiar with the dual tasking associated with walking whilst texting. Specifically, those individuals under the age of 30, such as those in the Plummer study, likely started using mobile phones. While we attempted to explore an ageing component within our study generally feel that the upper age limit within our study was not sufficient to separate out more robust ageing differences. However, our findings are generally consistent with previous research showing that when time constraints are imposed on participants, older individuals typically take longer or exhibit more cautious gate characteristics than their younger counter parts [23-25]. Though currently absent from the literature a more thorough investigation into the effects of simultaneous texting and walking, as older individuals are more susceptible to tripping (ref). While our study does support a greater risk for tripping for the age group we examined, other areas of walking behaviours that warrant attention include slower road crossing time and riskier road crossing behaviors, all of which are associated with an increased tripping and accident risk [9-12]. Others have shown that walking increases ones time spent looking away from obstacles by as much as 400% [8] leading to a phenomenon a known as “inattentional blindness” [26-28]. Citing a more humorous example, Hyman et al. (2010) showed that people using mobile phones were less likely to notice a unicycling clown performing along their walking route [29].

Our study presents for the first time gait characteristics associated with TXT and COG challenges while negotiating a serpentine course designed to emulate common outdoor walking tasks. Though we attempted to examine gender and aging affects by recruiting a more mature population, the age gap was likely insufficient to distinguish more robust obstacle course differences and we are therefore unable to generalize our findings beyond the age limits associated within our study cohort. We also cannot generalize to the potential effects of TXT and COG distractions associated with mobile phone use beyond our laboratory conditions. Our study is strengthened by our use of a crossover design, as well as our incorporation of an unfamiliar phone to decrease any phone-familiarity bias. In retrospect, our study would be enhanced by the use of eye-tracking technology, which would allow for more conclusions to be drawn regarding the attention prioritization encountered during course negotiation.

The present study supports the premise that gait is not a completely automated function and is altered by the addition of TXT and COG tasks. The minimal differences between the TXT and COG conditions in the present study potentially show that even though the conditions could require different cognitive responses, those under the age of 50 y are used to interacting with mobile technology whilst walking. Based on our findings, participants display a more conservative and hesitant gait in response to the dual-tasking situation of COG and TXT. The present study has, however, advanced the relevant field of research via the use of a more sophisticated methodology, which has in turn provided greater insight into the relationship between mobile phone usage gait alterations.

Acknowledgements. None.

Figures.

Figure 1. Schematic and dimensional representation of obstacle course obstacles. (**A**) Step Over Curb (Length = 0.105 m; width = 0.720 m; height 0.105 m), (**B**) Crossing Platform (Length = 2.030 m; width = 0.750 m; height = 0.092 m), (**C**) Step Obstacle: (Step 1; Length = 0.400 m; width = 0.400 m; height = 0.205 m, (**D**) Step 2; Length = 0.500 m; width = 0.500 m; height = 0.300 m), (**E**) Step 3; (Length = 0.585 m; width = 0.910 m; height = 0.110 m), (**F**) Model people (Length = 0.420 m; width = 0.530 m; height = 1.880 m).

Figure 2. Data represent mean and 95% confidence interval information for Course Time (Panel A), Step Length (Panel B), Double Support phase of walking (Panel C) and Obstacle Clearance Height for course barriers (Panel D). Statistical notations are: * 0.001 and ¶ 0.02.

Table 1: Course performance characteristics of participants negotiating obstacle course

	Distraction Challenge	Mean	SD	Significance vs. WLK	Partial Eta Squared
Course Time (sec)	Walk	19.32	2.3		
	Text	24.96	4.2	< 0.001	
	Cognitive	24.09	3.4	< 0.001	0.79
Walk Speed (m/sec)	Walk	0.78	0.1		
	Text	0.61	0.1	< 0.001	
	Cognitive [a]	0.63	0.1	< 0.001	0.88
Lateral Deviation from Straight Path	Walk	2.71	0.3		
	Text	2.76	0.3	NS	
	Cognitive	2.77	0.6	NS	0.04
Barrier Contact (n)	Walk	0.13	0.4		
	Text	0.23	0.4	NS	
	Cognitive	0.10	0.3	NS	0.10
Step Length (cm)	Walk	42.00	30.0		
	Text	36.00	20.0	< 0.001	
	Cognitive	37.00	20.0	< 0.001	0.87
Step Frequency (steps/sec)	Walk	1.84	0.2		
	Text	1.67	0.2	< 0.001	
	Cognitive [b]	1.71	0.2	< 0.001	0.62
Double Support Phase (sec)	Walk	170.00	30.0		
	Text	200.00	30.0	< 0.001	
	Cognitive	200.00	40.0	< 0.001	0.26
Obstacle Clearance Height (mm)	Walk	94.00	13.0		
	Text	111.00	19.0	< 0.001	
	Cognitive	110.00	23.0	<0.02	0.40

a = Significant vs. Text = 0.015
b = Significant vs. Text = 0.035

Table 2: Performance characteristics for individual obstacles

			Mean	SD	Significance vs. WLK	Partial Eta Squared
Time (ms)	Stair Approach	Walk	550.00	60.0		
		Text	580.00	90.0	0.074	
		Cognitive	590.00	70.0	0.004	0.267
	Platform Traverse	Walk	630.00	60.0		
		Text	710.00	110.0	< 0.001	
		Cognitive	710.00	100.0	< 0.001	0.453
	Stair Ascent	Walk	480.00	130.0		
		Text	570.00	90.0	0.000	
		Cognitive	550.00	70.0	0.008	0.414
Step count (n)	Stair Approach	Walk	1.24	0.4		
		Text	1.43	0.5		
		Cognitive	1.38	0.5		0.140
	Platform Traverse	Walk	1.07	0.3		
		Text	1.40	0.5	0.004	
		Cognitive	1.24	0.4	0.060	0.270
	Stair Ascent	Walk	1.10	0.3		
		Text	1.53	0.5	< 0.001	
		Cognitive	1.34	0.5	< 0.001	0.400
Step Frequency (steps/sec)	Stair Approach	Walk	1.83	0.2		
		Text	1.89	0.5	NS	
		Cognitive	1.83	0.5	NS	0.001
	Platform Traverse	Walk	1.61	0.2		
		Text	1.55	0.5	NS	
		Cognitive	1.44	0.2	< 0.001	0.556
	Stair Ascent	Walk	2.17	0.6		
		Text	1.80	0.4	0.005	
		Cognitive	1.87	0.3	0.014	0.266
Step Length (cm)	Stair Approach	Walk	69.70	17.1		
		Text	61.20	7.7	0.011	
		Cognitive	59.90	10.7	0.004	0.268
	Platform Traverse	Walk	72.40	7.0		
		Text	58.40	15.7	0.001	
		Cognitive	64.60	9.4	0.001	0.486
	Stair Ascent	Walk	54.40	23.8		
		Text	48.70	18.2	NS	
		Cognitive	50.80	14.6	NS	0.087
Double Support Phase (ms)	Stair Approach	Walk	150.00	30.0		
		Text	170.00	40.0	0.004	
		Cognitive	170.00	20.0	< 0.001	0.483

	Platform	Walk	170.00	70.0		
	Traverse	Text	190.00	40.0	NS	
		Cognitive	200.00	80.0	NS	0.097
	Stair	Walk	220.00	120.0		
	Ascent	Text	290.00	150.0	NS	
		Cognitive	280.00	160.0	<0.001	0.440
Clearance Height (mm)	Stair	Walk	135.00	26.0		
	Approach	Text	159.00	41.0	<0.001	
		Cognitive	148.00	51.0	NS	0.365
	Platform	Walk	65.00	26.0		
	Traverse	Text	65.00	22.0	NS	
		Cognitive	65.00	32.0	NS	0.000
	Stair	Walk	73.00	14.0		
	Ascent	Text	97.00	37.0	0.003	
		Cognitive	99.00	22.0	<0.001	0.615

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Figure 1

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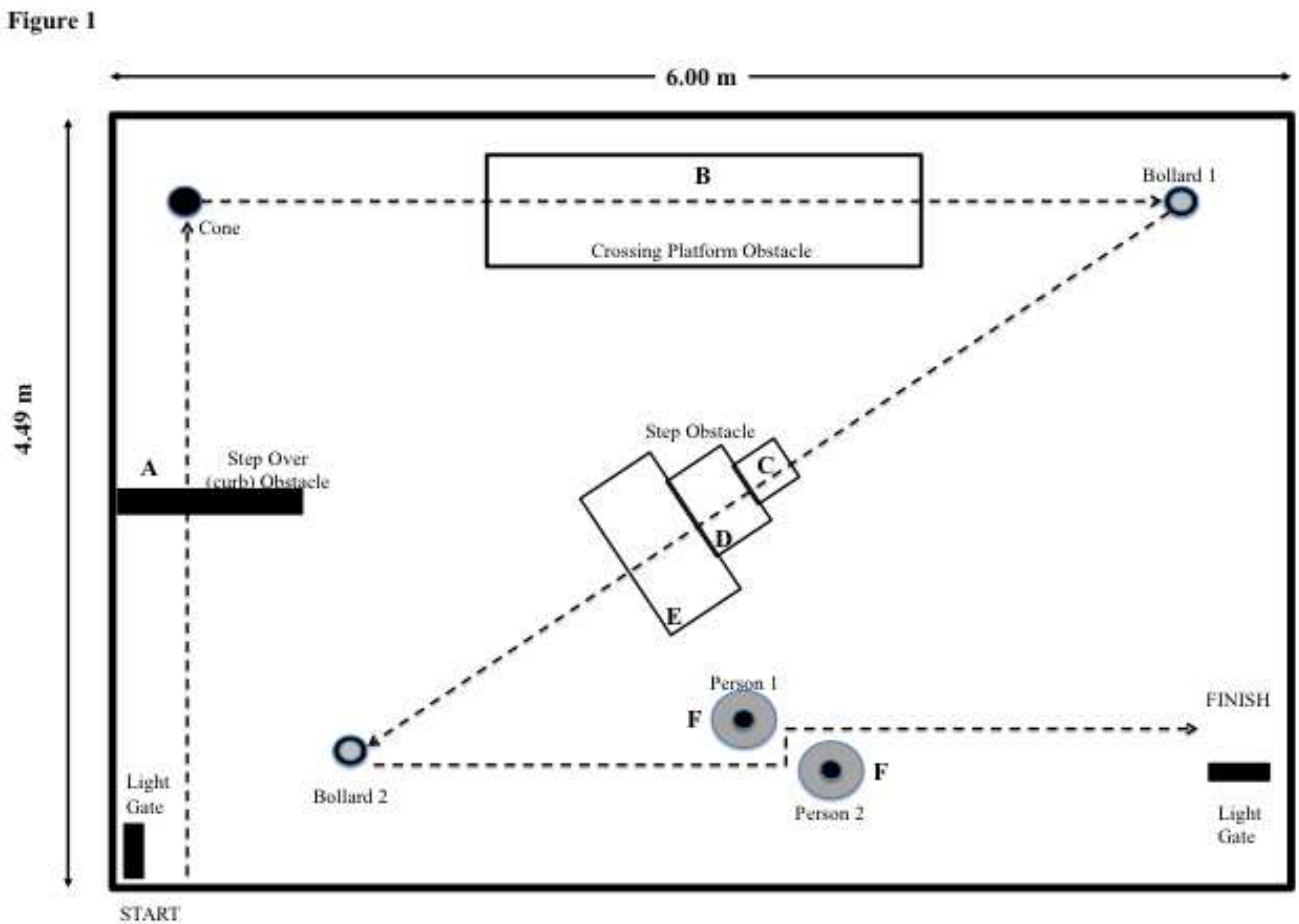

Figure 2
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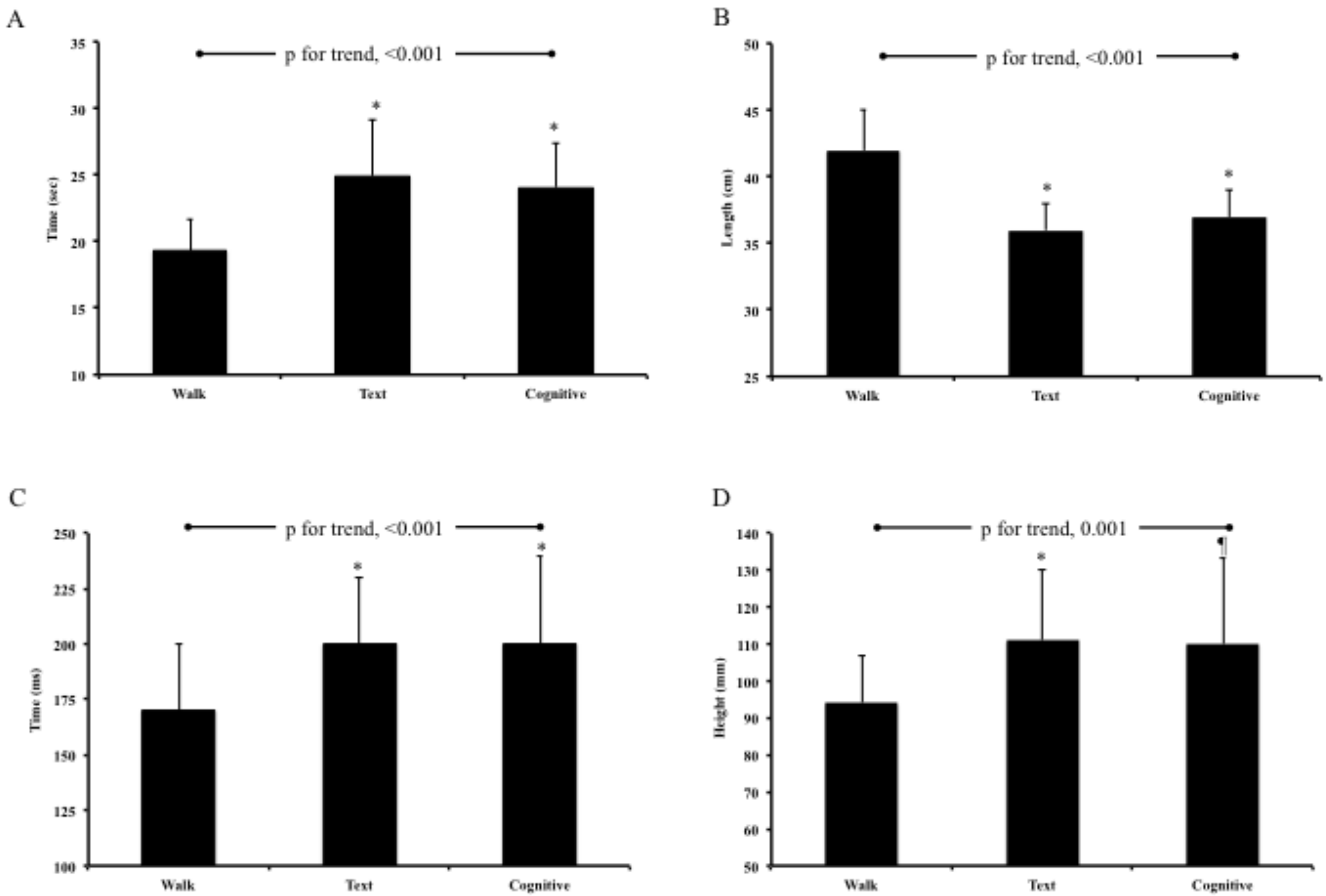
Figure 2



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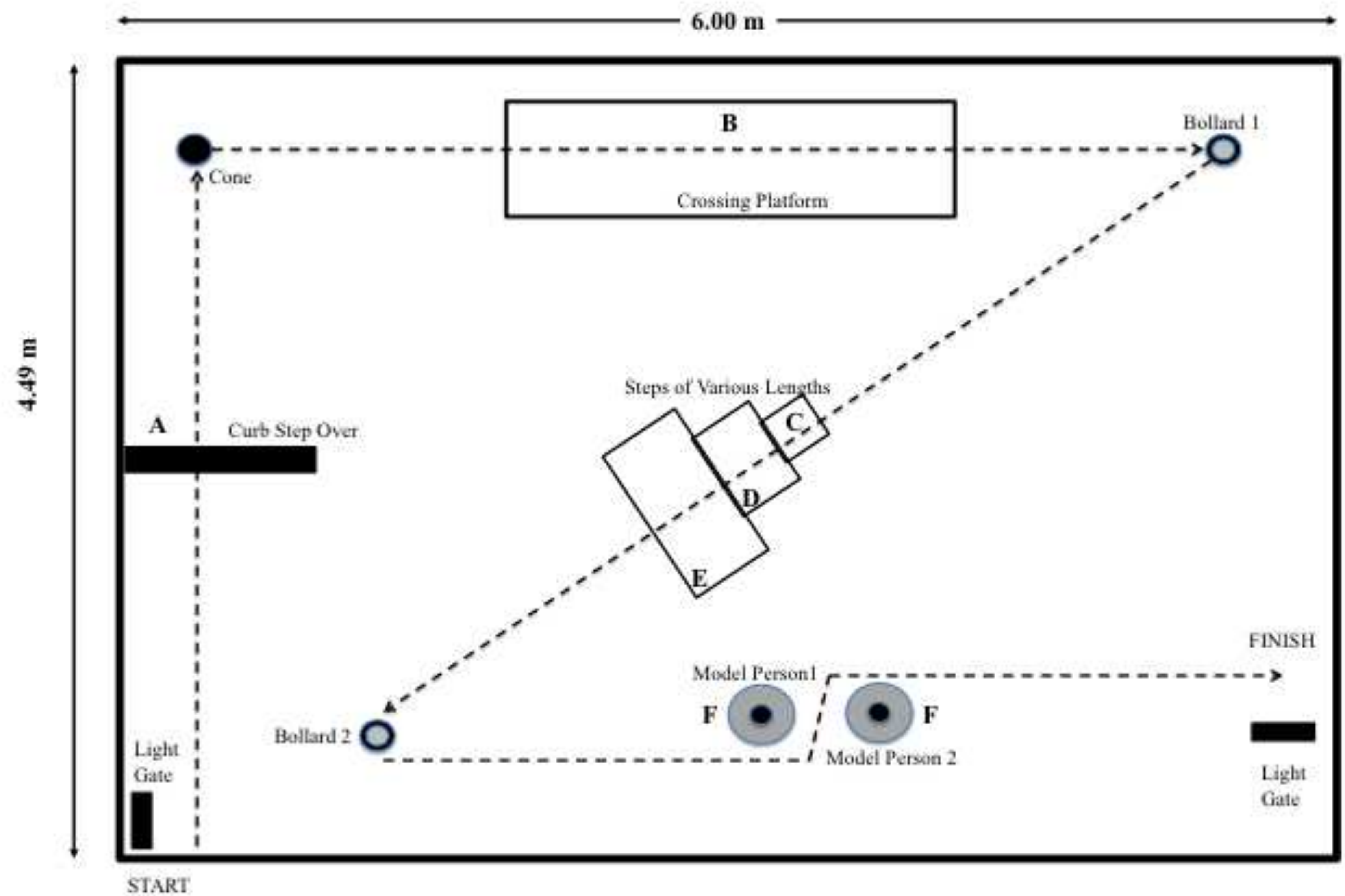

Title. Gait pattern alterations during walking, texting and walking and texting during cognitively distractive task while negotiating common pedestrian obstacles

Running Head. Texting and Cognitive Distraction during Walking

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Key words: Mobile phone, Texting, Gait, Balance

ABSTRACT.

Objectives. Mobile phone texting is a common daily occurrence with a paucity of research examining corresponding gait characteristics. To date, most studies have participants walk in a straight line vs. overcoming barriers and obstacles that occur during regular walking. The aim of our study is to examine the effect of mobile phone texting during periods of cognitive distraction while walking and negotiating barriers synonymous with pedestrian traffic.

Methods. Thirty participants (18-50y) completed three randomized, counter-balanced walking tasks over a course during: (1) normal walking (control), (2) texting and walking, and (3) texting and walking whilst being cognitively distraction via a standard mathematical test performed while negotiating the obstacle course. We analyzed gait characteristics during course negotiation using a 3-dimensional motion analysis system and a general linear model and Dunnet-Hsu post-hoc procedure the normal walking condition to assess gait characteristic differences. Primary outcomes included the overall time to complete the course time and barrier contact. Secondary outcomes included obstacle clearance height, step frequency, step time, double support phase and lateral deviation.

Results. Participants took significantly longer (mean ± SD) to complete the course while texting (24.96±4.20 sec) and during cognitive distraction COG (24.09±3.36 sec) vs. normal walking (19.32±2.28 sec; *all*, $P<0.001$). No significant differences were noted for barrier contacts ($P = 0.28$). Step frequency, step time, double support phase and lateral deviation all increased in duration during the texting and cognitive distraction trial. Texting and being cognitively distracted also increased obstacle clearance versus the walking condition (*all*, $P<0.02$).

Conclusions. Texting while walking and/or being cognitively distracted significantly affect gait characteristics concordant to mobile phone usage resulting in a more cautious gate pattern.

Future research should also examine a similar study in older participants who may be at a greater risk of tripping with such walking deviations.

INTRODUCTION

Mobile and Smartphone has increased internationally and it is now estimated that Smartphone ownership will increase from an estimated 34.3% in 2011 to a projected 58.2% in 2015 in the United Kingdom [1,2]. Coupled to Smartphone ownership is an increase in mobile messaging inclusive of texting, SMS, Internet, social media access and emailing. For simplicity we will use "text" to denote various Internet communication functions. To this end, texting has increased in the United Kingdom from 27 billion in 2004 to 129 billion in 2012 [3]. While text growth facilitates communication it also increases the risk of distraction during walking, which may in turn carry with it an increased risk for tripping, collision or secondary injuries to other pedestrians attempting to avoid those who are texting and deviating from a normal path of ambulation. While the risk associated with texting is well-recognized during driving, the potential hazards associated with walking are not as well established [4-6].

Few studies have investigated walking and texting and fewer yet the simultaneous negotiation of an obstacle course [7]. This is an important consideration as "real life" requires the user to look away from pathway obstacles in order to text [8]. As such, texting while walking disrupts gait speed, potentially increasing road crossing time and riskier road crossing behaviors, possibly increasing tripping and accident risk [9-12]. While most studies use fairly simplistic models, we are unaware of research using more circuitous obstacle courses designed and built to represent common pedestrian obstacles such as curbs, people, steps, etc. The primary aim of our study is to examine the effect texting on gait characteristics while negotiating common pedestrian obstacles. We hypothesize that texting will affect normal gait characteristics and increase barrier contacts, a surrogate for tripping, while negotiating steps, ramps and obstacles representing pedestrian traffic.

METHODS

Participants

We recruited thirty participants (18 females; 18-50 years) to take part in our study approved by the University of Bath Department for Health Ethics Advisory Panel. We included only participants who owned their own mobile phone for more than one month and excluded candidates taking medications that may cause dizziness. All participants signed an informed consent outlining the study aims and procedures. Subsequently, participants completed questionnaires regarding their current mobile phone use and a physical-activity readiness questionnaire [13].

Experimental Procedures

Before initiating formal testing procedures, participants completed a familiarization session of the obstacle course under each testing condition: (1) walking with no distraction (WLK, control), (2) responding to standardized texting questions on their own phone (TXT) and (3) completing a mental mathematics quiz (AB Math Lite 5.3) on an iPhone™ (Apple, Cupertino, CA US phone (COG). All participants were instructed not to look at either the messages or the mental mathematics quiz until they began walking. All walking conditions were administered in a randomized, counter-balanced manner.

The obstacle course was designed to mimic obstacles one would encounter in everyday life (**Figure 1**) and consisted of seven obstacles designed and based on fieldwork within the City Centre of Bath, UK:

(1) An obstacle resembling a curb to step over,

(2) A platform to step-on, step-off platform,

(3) A set of uneven steps,

(4-5) Two traffic bollards to step around and,

(6-7) Two dummies of sufficient height representing model people for participants to step around

We used a 3D optical motion analysis system (Qualisys, Sweden), with 13 Oqus 4 cameras set-up to collect kinematic data whilst the participants negotiated the obstacle course in each of the conditions. Six reflective markers were attached to each participant using double sided tape: two on each shoe (n=4), one approximately over the 5th metatarsal-phalangeal (MTP) joint and one on the back of the heel, and two on an elasticated band worn around the pelvis. The two pelvis markers were positioned on either side of the spine, approximately over the posterior superior iliac spines. The elasticated band was used to provide a tight fitting surface to which to attach the pelvis markers as the participants undertook the testing in their everyday clothes. We also placed photocell light gates (Powertimer 1.0, Newtest, Finland) at the start and finish of the course to measure time to complete the course. Reflective markers were placed on every obstacle on the corners of the front edge of each obstacle except for the two model people. The 3D positions of the markers on the participant and the markers on the obstacles were determined at 100Hz. From these data we calculated the velocity of the participant and various step characteristics as they negotiated the course (**Fig. 1**). Data from Qualisys was imported into an Excel spreadsheet in order to perform requisite calculations. No filtering was applied or data adjusted we only looked at marker displacement of the markers and did not investigate velocity or acceleration.

Step Characteristics

To calculate step characteristics we determined the timings of heel strike and toe-off using an algorithm developed by Zeni Jr. et al. (2008). [14] This entailed finding the coordinates of the mid-point of the pelvis markers and subtracting this from the coordinates of heel and 5th MTP markers. Heel strike was defined as the point at which the heel was at a maximum distance in front of the hip and toe-off as the point at which the 5th MTP was at a maximum distance behind the hip. Based upon the timings and positions of heel strike and toe off of each step the following parameters were determined and where appropriate a mean value calculated over the course:

- *Step count*: the number of steps taken for the obstacle course
- *Step time*: the time between the heel strike of one foot and the heel strike of the contralateral foot
- *Step frequency*: the number of steps per second
- *Step length*: the distance between the position of the heel marker at heel strike of one foot and the position of the heel marker at heel strike of the contralateral foot
- *Double support phase*: the time between second foot heel strike and first foot toe off or the time during which both feet were in contact with the ground
- *Barrier clearance*: the difference between the 5th MTP marker vertical coordinate and the barrier vertical coordinate at the time the 5th MTP joint arrived at the obstacle.

We also performed a sub-analysis to examine some of these gait characteristics during the approach and negotiation of the obstacles. *Stair approach* is defined as each respective gait characteristic observed in the 1.5 m immediate prior to negotiating the stairs. *Stair ascent* is defined as each respective gait characteristic observed in the ascending the stairs. *Platform traverse* is each respective gait characteristic observed while traversing the platform.

In addition to the outcome measures defined above, the deviation from a straight path was investigated during the first two sides of the obstacle course. This part of the course was chosen as it involved two clearly defined straight channels with a 90° turn between them (Figure 1). The length of the straight-line path of the first and second sides of the course was determined from the co-ordinates of the centre of the beginning and the end of the path for these two sides (as defined by cones and markers on the ground). The length of the path travelled by the participants was defined as the cumulative displacement of the centre of the pelvis markers along the first and second sides of the course. This was calculated by determining the centre point of the two pelvis markers at each time point, calculating the displacement of this point between each time point and summing these from the beginning of the course until the participant reached the end of the second side. The deviation from walking a straight path was determined by subtracting the straight path distance from the actual path travelled.

Statistical Analysis

We examined our data using a general linear model covaried for the control/WLK condition using SPSS (v21). Data sphericity was accounted for via a Greenhouse-Geisser correction. Post-hoc analyses were performed using a Dunnett-HSU analysis to compare TXT and COG to the WLK condition. We also performed Pearson correlations between various gait characteristics and barrier contact in an effort to associate potential gait characteristics and tripping risk. All data is presented as mean ± standard deviation (SD) or 95% confidence intervals where appropriate. Statistical significance was established at $P \leq 0.05$. The effect size is presented as the partial eta squared for each analysis.

RESULTS.

Course Performance Characteristics

We have presented the overall findings for negotiating the complete course in **Table 1**. Overall, we found that it took significantly longer to complete the course due to slower walking speeds under the TXT and COG conditions vs. WLK (*all*, P<0.001, **Fig. 2A**). In support of these observations, participants exhibited significantly shorter step lengths (**Fig. 2B**), lower step frequencies, longer double support phases (**Fig. 2C**), and greater obstacle clearance heights while TXT and COG vs. WLK (all, P<0.001, **Fig. 2D**). While the COG condition was significantly different to TXT for walking speed (P<0.02) and step frequency (P<0.04), no other significant differences were noted between the TXT and COG conditions. Despite these alterations in gait characteristics we did not observe any changes in barrier contacts during any treatment condition (P = 0.10).

Performance Characteristics for Individual Obstacles

We have presented the findings for negotiating each individual obstacle in **Table 2**.

Step Approach. When negotiating the 1.5 m approach to the steps, we did not observe a significant difference to the step count or step frequency on the approach. However, we did observe a significantly greater length of time to the approach for the COG condition and a strong trend for significance during the TXT condition (P=0.07) due to a significant reduction in step length and double support phase for the TXT (P=0.011) and COG conditions (P=0.004). While we also observed a greater step clearance height for the TXT condition (P<0.001), we did no observe a significant for the COG condition.

Platform Traverse. Overall, it took longer to negotiate the platform during the TXT and COG conditions (all, P<0.001) vs. WLK with no distraction. This was due, in part, to a greater step count for the TXT condition (P=0.004) and strong trend for the COG condition (P=0.06). Other contributing factors for this observation included a shorter step frequency for the COG condition (P<0.001) and shorter step lengths for the TXT and COG condition (*both*, P<0.001). No significant differences were noted for the double support phase or clearance height.

Stairs Ascent. Negotiating the stairs took significantly longer during the TXT ($P<0.001$) and COG conditions $P=0.008$). Contributing factors for this observation included a greater step count during the TXT and COG conditions ($P<0.001$), a greater step frequency during the TXT ($P=0.005$) and COG conditions ($P=0.014$), and greater clearance heights whilst negotiating the stairs for the TXT ($P=0.003$) and COG conditions ($P<0.001$). No significant differences were noted for step length or the double support phase of stair ascent.

DISCUSSION

The primary aim of our study was to examine the effect of a TXT and COG challenge on gait characteristics during concomitant walking and mobile phone use. Our primary findings show that TXT and COG significantly shorten step length, reduce step frequency, lengthen double phase support and increase obstacle clearance height. Our secondary outcome analysis also shows a similar pattern alterations relative to each respective obstacle encountered over the course. Specifically, participants altered their approach to stairs, subsequent stair ascent obstacle step clearance height and the negotiation of platforms under the TXT and COG conditions. Thus, we accept our first research hypothesis that TXT and COG significantly alters gait characteristics during walking. While one might infer that these alterations in gait might increase the risk for tripping, our surrogate analysis (i.e., barrier contacts) showed no significant differences between any treatment conditions. Therefore, we reject our hypothesis that TXT and COG would increase the occurrence barrier contact and that the connection between gait alterations, deviations from walking a straight path and tripping becomes tenuous. Our results, in conjunction with others [15-17], suggest that those who walk and text adopt a "protective" gait pattern alteration in order to minimize the risk of potential accidents.

Overall, the adoption of a more conservative locomotion strategy involves a decreased walking velocity and foot placement adjustment before encountering an obstacle [15-17]. Some hypothesize that when faced with a cognitive challenge, posture and gait function are prioritized over cognitive demands, as posture and gait operate at a more subconscious level [18,19]. Whether the change in gait pattern in our study is conscious or sub-conscious is currently indeterminable; however, the decrease in walking velocity associated with a TXT and COG challenge in our study coupled with previous literature examining other populations examining walking support this hypothesis [10,15-17,20,21]. In essence, when faced with the dual task challenge of walking and texting while undergoing a cognitive challenge, participants decrease their walking speed to avoid accidents [22]. The results from the present study support this mechanism given that participants displayed adaptive changes in gait patterns during the TXT and COG conditions. As it pertains to texting our findings differ to those recently published by Plummer et al (2015) who demonstrated no significant gait alterations using a single and dual task assessment of walking and texting in 32 young adults (18 - 30 y) [19]. We propose several reasons for these differences.

First, Plummer et al (2015) used a straight course pathway free of obstacles, while our course was circuitous and incorporated common pedestrian obstacles. Second, we used a broader age range (18–50 y), which may have introduced a “familiarity” component as younger individuals are more likely to be familiar with the dual tasking associated with walking whilst texting. Specifically, those individuals under the age of 30, such as those in the Plummer study, likely started using mobile phones. While we attempted to explore an ageing component within our study generally feel that the upper age limit within our study was not sufficient to separate out more robust ageing differences. However, our findings are generally consistent with previous research showing that when time constraints are imposed on participants, older individuals typically take longer or exhibit more cautious gate characteristics than their younger counter parts [23-25]. Though currently absent from the literature a more thorough investigation into the effects of simultaneous texting and walking, as older individuals are more susceptible to tripping (ref). While our study does support a greater risk for tripping for the age group we examined, other areas of walking behaviours that warrant attention include slower road crossing time and riskier road crossing behaviors, all of which are associated with an increased tripping and accident risk [9-12]. Others have shown that walking increases ones time spent looking away from obstacles by as much as 400% [8] leading to a phenomenon a known as "inattentional blindness" [26-28]. Citing a more humorous example, Hyman et al. (2010) showed that people using mobile phones were less likely to notice a unicycling clown performing along their walking route [29].

Our study presents for the first time gait characteristics associated with TXT and COG challenges while negotiating a serpentine course designed to emulate common outdoor walking tasks. Though we attempted to examine gender and aging affects by recruiting a more mature population, the age gap was likely insufficient to distinguish more robust obstacle course differences and we are therefore unable to generalize our findings beyond the age limits associated within our study cohort. We also cannot generalize to the potential effects of TXT and COG distractions associated with mobile phone use beyond our laboratory conditions. Our study is strengthened by our use of a crossover design, as well as our incorporation of an unfamiliar phone to decrease any phone-familiarity bias. In retrospect, our study would be enhanced by the use of eye-tracking technology, which would allow for more conclusions to be drawn regarding the attention prioritization encountered during course negotiation.

The present study supports the premise that gait is not a completely automated function and is altered by the addition of TXT and COG tasks. The minimal differences between the TXT and COG conditions in the present study potentially show that even though the conditions could require different cognitive responses, those under the age of 50 y are used to interacting with mobile technology whilst walking. Based on our findings, participants display a more conservative and hesitant gait in response to the dual-tasking situation of COG and TXT. The present study has, however, advanced the relevant field of research via the use of a more sophisticated methodology, which has in turn provided greater insight into the relationship between mobile phone usage gait alterations.

Acknowledgements. None.

Figures.

Figure 1. Schematic and dimensional representation of obstacle course obstacles. (**A**) Step Over Curb (Length = 0.105 m; width = 0.720 m; height 0.105 m), (**B**) Crossing Platform (Length = 2.030 m; width = 0.750 m; height = 0.092 m), (**C**) Step Obstacle: (Step 1; Length = 0.400 m; width = 0.400 m; height = 0.205 m, (**D**) Step 2; Length = 0.500 m; width = 0.500 m; height = 0.300 m), (**E**) Step 3; (Length = 0.585 m; width = 0.910 m; height = 0.110 m), (**F**) Model people (Length = 0.420 m; width = 0.530 m; height = 1.880 m).

Figure 2. Data represent mean and 95% confidence interval information for Course Time (Panel A), Step Length (Panel B), Double Support phase of walking (Panel C) and Obstacle Clearance Height for course barriers (Panel D). Statistical notations are: * 0.001 and ¶ 0.02.

Table 1: Course performance characteristics of participants negotiating obstacle course

	Distraction Challenge	Mean	SD	Significance vs. WLK	Partial Eta Squared
Course Time (sec)	Walk	19.32	2.3		
	Text	24.96	4.2	< 0.001	
	Cognitive	24.09	3.4	< 0.001	0.79
Walk Speed (m/sec)	Walk	0.78	0.1		
	Text	0.61	0.1	< 0.001	
	Cognitive [a]	0.63	0.1	< 0.001	0.88
Lateral Deviation from Straight Path	Walk	2.71	0.3		
	Text	2.76	0.3	NS	
	Cognitive	2.77	0.6	NS	0.04
Barrier Contact (n)	Walk	0.13	0.4		
	Text	0.23	0.4	NS	
	Cognitive	0.10	0.3	NS	0.10
Step Length (cm)	Walk	42.00	30.0		
	Text	36.00	20.0	< 0.001	
	Cognitive	37.00	20.0	< 0.001	0.87
Step Frequency (steps/sec)	Walk	1.84	0.2		
	Text	1.67	0.2	< 0.001	
	Cognitive [b]	1.71	0.2	< 0.001	0.62
Double Support Phase (sec)	Walk	170.00	30.0		
	Text	200.00	30.0	< 0.001	
	Cognitive	200.00	40.0	< 0.001	0.26
Obstacle Clearance Height (mm)	Walk	94.00	13.0		
	Text	111.00	19.0	< 0.001	
	Cognitive	110.00	23.0	<0.02	0.40

a = Significant vs. Text = 0.015
b = Significant vs. Text = 0.035

Table 2: Performance characteristics for individual obstacles

			Mean	SD	Significance vs. WLK	Partial Eta Squared
Time (ms)	Stair	Walk	550.00	60.0		
	Approach	Text	580.00	90.0	0.074	
		Cognitive	590.00	70.0	0.004	0.267
	Platform	Walk	630.00	60.0		
	Traverse	Text	710.00	110.0	< 0.001	
		Cognitive	710.00	100.0	< 0.001	0.453
	Stair	Walk	480.00	130.0		
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		Cognitive	550.00	70.0	0.008	0.414
Step count (n)	Stair	Walk	1.24	0.4		
	Approach	Text	1.43	0.5		
		Cognitive	1.38	0.5		0.140
	Platform	Walk	1.07	0.3		
	Traverse	Text	1.40	0.5	0.004	
		Cognitive	1.24	0.4	0.060	0.270
	Stair	Walk	1.10	0.3		
	Ascent	Text	1.53	0.5	< 0.001	
		Cognitive	1.34	0.5	< 0.001	0.400
Step Frequency (steps/sec)	Stair	Walk	1.83	0.2		
	Approach	Text	1.89	0.5	NS	
		Cognitive	1.83	0.5	NS	0.001
	Platform	Walk	1.61	0.2		
	Traverse	Text	1.55	0.5	NS	
		Cognitive	1.44	0.2	< 0.001	0.556
	Stair	Walk	2.17	0.6		
	Ascent	Text	1.80	0.4	0.005	
		Cognitive	1.87	0.3	0.014	0.266
Step Length (cm)	Stair	Walk	69.70	17.1		
	Approach	Text	61.20	7.7	0.011	
		Cognitive	59.90	10.7	0.004	0.268
	Platform	Walk	72.40	7.0		
	Traverse	Text	58.40	15.7	0.001	
		Cognitive	64.60	9.4	0.001	0.486
	Stair	Walk	54.40	23.8		
	Ascent	Text	48.70	18.2	NS	
		Cognitive	50.80	14.6	NS	0.087
Double Support Phase (ms)	Stair	Walk	150.00	30.0		
	Approach	Text	170.00	40.0	0.004	
		Cognitive	170.00	20.0	< 0.001	0.483

	Platform	Walk	170.00	70.0		
	Traverse	Text	190.00	40.0	NS	
		Cognitive	200.00	80.0	NS	0.097
	Stair	Walk	220.00	120.0		
	Ascent	Text	290.00	150.0	NS	
		Cognitive	280.00	160.0	<0.001	0.440
Clearance Height (mm)	Stair	Walk	135.00	26.0		
	Approach	Text	159.00	41.0	<0.001	
		Cognitive	148.00	51.0	NS	0.365
	Platform	Walk	65.00	26.0		
	Traverse	Text	65.00	22.0	NS	
		Cognitive	65.00	32.0	NS	0.000
	Stair	Walk	73.00	14.0		
	Ascent	Text	97.00	37.0	0.003	
		Cognitive	99.00	22.0	<0.001	0.615

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Dear Editor and Reviewers.

Thank you for your time and consideration of our manuscript. We appreciate the time you have taken out of your schedules to do so and present responses to your comments below.

5. Review Comments to the Author

Please use the space provided to explain your answers to the questions above. You may also include additional comments for the author, including concerns about dual publication, research ethics, or publication ethics. (Please upload your review as an attachment if it exceeds 20,000 characters)

Reviewer #1: The manuscript is generally well written and addresses a relevant topic in a scientifically rigorous manner. The authors have presented a well-designed study.

[Comments]

1. The greatest weakness is the disconnect between the Introduction and the Discussion sections. In both cases, the authors present information that does not directly support the rationale for the current study. In addition, there is a lack of coherence between the two sections.

2. The second paragraph of the Introduction starts to drift away from the purpose of the study. The link between blood alcohol level and driving does not seem germane to this study, rather it distracts from the purpose of the study. It is not clear how studies of blood alcohol levels and texting during driving support the significance of this study.

The second paragraph of the Introduction starts to drift away from the purpose of the study. The link between blood alcohol level and driving does not seem germane to this study, rather it distracts from the purpose of the study. It is not clear how studies of blood alcohol levels and texting during driving support the significance of this study.

[Response] Per comments 1 & 2. We have made extensive revisions to the Introduction and Discussion in an effort to rectify this.

General comments:

Introduction

[Comment] In the 4th line of the second paragraph the authors state that there are 3 studies that have used controlled laboratory experiments, yet they cite 10 studies?

[Response] We see how this is confusing and have re-worded the text. In brief, we are referring to 10 studies examining walking and texting, 3 of which used laboratory conditions.

[Comment] Last paragraph of Introduction; replace “we will use” with “we used”

[Response] Done.

Methods

[Comment] Were the testing protocols randomized?

[Response] Yes. We have clarified this in the Methods at the end of the first paragraph as: “All walking conditions were administered in a randomized, counter-balanced manner.”

[Comment] How was the motion capturing data processed? Filtering parameters, etc.?

[Response] We have changed the Methods to reflect the following. In brief, data from Qualisys was imported into Excel in order to perform our requisite calculations. No filtering was applied or data adjusted we only looked at marker displacement of the markers and did not investigate velocity or acceleration.

Discussion

[Comment] The Discussion section seems disconnected from the Introduction. It is suggested that the authors re-write these sections in a more coherent manner.

[Response] We have made extensive revisions to the Introduction and Discussion in an effort to rectify this.

[Comment] It is unclear how the results of this study relate to previous studies on age and obstacle clearance? At a minimum this information should be presented in the introduction (perhaps in place of the discussion of blood alcohol levels) if the authors are going to link distracted walking with age related changes in walking.

[Response] We have elected to minimize the discussion on the ageing component, as the older group is still relatively young and only waters down the primary findings of the study.

[Comment] Similar to previous comment, the section on inattentional blindness does not seem to directly relate to the current study. Eye tracking tools were not utilized to assess gaze characteristics. It is suggested that this section be removed.

[Response] We have minimalized the discussion on this but feel some attention relative to the idea should be made.

[Comment] The last sentence of the Discussion is not appropriate. The study did not address this subject in any way.

[Response] We have removed this sentence.

[Comment] Reviewer #2: Overall, the paper needs to be edited for better wording and to be more concise and clear. Currently, the introduction and discussion are sloppy with several typographical errors, and with similar wording repeated.

[Response] We have made extensive revisions to the Introduction and Discussion in an effort to rectify this.

[Comment] Statistics do not have enough specifics. % of what population for the billions of texts sent?

[Response] We have attempted to clarify this in the Introduction and cite reports accordingly

[Comment] Introduction is weak. The comparison to blood alcohol content does not seem directly related to the current proposed study. The arguments seem to reach rather than be directly related.

[Response] We have attempted to refine the Introduction for clarity.

[Comment] It is unrealistic to step over dummies. Do pedestrians generally need to step over people?

[Response] We are sorry that you took this so literally and would have thought this would be intuitive. Nonetheless, we have added verbiage denoting that participants stepped around both the bollards and the dummies.

Methods:

[Comment] The number of subjects is appropriate.

[Response] No comment required

[Comment] It is unclear about how the dummies are placed when reading the text in the methods. p. 5

[Response] We apologize but this comment lacks in detail so are unable to comment on your point of confusion. We have made some effort to clarify this section and hope that it will suffice.

It now reads:

The obstacle course was designed to mimic obstacles one would encounter in everyday life (**Figure 1**) and consisted of seven obstacles designed based on fieldwork within the City Centre of Bath, UK:

(1) An obstacle resembling a curb to step over,
(2) A platform to step-on, step-off platform,
(3) A set of uneven steps,
(4-5) Two traffic bollards to step around and,
(6-7) Two dummies of sufficient height to represent people for participants to step around

Results

[Comment] First sentence of Results section should be deleted. The reference to Table 1 should be given in a sentence that presents results.

[Response] We respectfully disagree and feel quite the opposite. Anecdotally, I (C. Earnest) have found that readers appreciate being told where the data to be discussed will be found *before* the presentation of those particular findings. Since this is not a requirement of the journal we will have to agree to disagree on the placement of this line.

[Comment] Third sentence of Results states "supporting these observations are observations . . . " This is redundant wording, please edit.

[Response] Thank you for bringing this to our attention. The section has been changed to read:

Supporting these observations, participants exhibited significantly shorter step lengths (**Fig. 2B**), ……

[Comment] Second paragraph of results, delete first sentence and refer to Table 2 in a sentence that gives results information.

[Response] Again, we respectfully disagree and feel quite the opposite. (copied from above) Anecdotally, I (C. Earnest) have found that readers appreciate being told where the data to be discussed will be found *before* the presentation of those particular findings. Since this is not an editorial requirement of the journal we will have to agree to disagree on this point.

Discussion

[Comment] The results are over extended. Avoid wording such as "natural sequelue." You need to make a direct connection to tripping risk or state the connection as possible but not proven. Typographical error also exists in this sentence, you state "risk or tripping."

[Response] We have modified this section to read:

“While one might infer that these alterations in gain might to an increased risk for tripping, our surrogate analysis (i.e., barrier contacts) showed no significant differences for any treatment condition.”

[Comment] The Discussion contains conjecture and needs to be edited to be shorter and more directly related to the findings of the study. Please shorten the Discussion and cite only papers that directly relate to findings of the current study.

[Response] The Discussion has been revised, shortened, and hopefully made more concise.

Figure captions

[Comment] Use “model people” instead of dummies. Please be consistent in your wording and description of the obstacles in the methods and in figure captions.

[Response] Good point. We have changed this and have modified Figure 1 legend to better match the figure itself.

References

[Comment] Only 1 reference is given from 2014. Please complete another literature search and ensure no other recent studies have investigated texting and walking.

[Response] Good suggestion. We have found one applicable reference by Plummer et. al (2015) which has been added to be paper.